Shore & Beach, Vol. 71, No. 4, 2003, pp. 7-12.

"Threes," an Unusual Surfing Spot at Shinnecock Inlet, New York

By

Frank S. Buonaiuto
Coastal Consultant
2 Dawnwood Drive
Manorville, NY 11949
fsbuonaiuto@optonline.net

Zeki Demirbilek, Nicholas C. Kraus
U.S. Army Engineer Research and Development Center
Coastal and Hydraulics Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180
Zeki.Demirbilek@erdc.usace.army.mil, Nicholas.C.Kraus@erdc.uscace.army.mil

ABSTRACT

Interactions among waves, tide, wind, jetties, and inlet morphology create and enhance surfable waves within Shinnecock Inlet, New York. "Threes," a popular local surf break, can be experienced only during certain combinations of incident wave height, period, direction, and wind direction and tidal elevation. Threes is activated if waves from the south-southeast to south-southwest propagate into the inlet, reflect first off the east jetty, then off the west jetty, and break on a bayside shoal extending from the western barrier island. In maintenance of the jetties at Shinnecock Inlet, the U.S. Army Corps of Engineers tries to accommodate requests of surfers for preserving conditions favorable for Threes. Observations indicate Threes can only be surfed around slack low tide, when the tidal current velocity in the inlet is weak. The resulting waves can reach approximately 1.5 to 2 m in height and plunge along the shoal for 20 to 30 m, giving a surfing duration of 5 to 8 sec. In this paper, the Threes phenomenon is discussed and successfully simulated with the CGWAVE numerical model. An implication is that surfing amenities can be reliably designed with numerical models.

Additional Keywords: Inlet, reflection, refraction, tidal current, shoaling, CGWAVE

INTRODUCTION

Surfers often give descriptive names to surfing hot spots to denote the kind of ride experienced. There are many such colorful names in the surfing subculture, including "Jaws" in Maui and the "Pipeline" in Oahu, both in Hawaii, and "The Wedge" at the west jetty of Newport Beach, California. Another interesting name is "Threes," referring to a location at the bay side of the west jetty at Shinnecock Inlet, Long Island, New York.

Threes (Figure 1) owes its name to the waves incident from the Atlantic Ocean that are twice reflected between two jetties, under certain circumstances as are discussed here.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **'Threes,' an Unusual Surfing Spot at Shinnecock Inlet, New York**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,Coastal and Hydraulics Laboratory,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Interactions among waves, tide, wind, jetties, and inlet morphology create and enhance surfable waves within Shinnecock Inlet, New York. "Threes," a popular local surf break, can be experienced only during certain combinations of incident wave height, period, direction, and wind direction and tidal elevation. Threes is activated if waves from the south-southeast to south-southwest propagate into the inlet, reflect first off the east jetty, then off the west jetty, and break on a bayside shoal extending from the western barrier island. In maintenance of the jetties at Shinnecock Inlet, the U.S. Army Corps of Engineers tries to accommodate requests of surfers for preserving conditions favorable for Threes. Observations indicate Threes can only be surfed around slack low tide, when the tidal current velocity in the inlet is weak. The resulting waves can reach approximately 1.5 to 2 m in height and plunge along the shoal for 20 to 30 m, giving a surfing duration of 5 to 8 sec. In this paper, the Threes phenomenon is discussed and successfully simulated with the CGWAVE numerical model. An implication is that surfing amenities can be reliably designed with numerical models.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**19**	

The incident wave reflecting off the east jetty is wave 1, the reflected wave that arrives at the west jetty is wave 2, and the wave reflected off the west jetty that can be surfed is wave 3. Waves 2 and 3 pass over a large tip shoal present at the base of the west jetty. Formation of Threes is an infrequent occurrence, and surfers on Long Island are on the alert for favorable wave conditions conducive to its breaking.

This paper examines the necessary conditions for creating Threes and includes graphics from a numerical simulation demonstrating the phenomenon. The suppression or the enhancement of Threes depends on a certain window of combined tide and wave conditions, as well as on the presence of a shoal and reflective structural condition of the jetties, bringing to play many aspects of coastal processes and engineering. We also discuss why Threes is important to the local surfing population and how such tidal inlet processes can be described by means of state-of-the-art numerical simulation technology.

SHINNECOCK INLET AND SURFING

Shinnecock Inlet is located on the south shore of Long Island, New York, 59 km west of Montauk Point, and it is the eastern-most of six stabilized inlets located along the barrier island chain (Figure 2). The modern inlet opened in September 1938 during the passage of the Great New England Hurricane. Local interests constructed a revetment on the west side of the inlet in 1947, probably to halt westward migration of the inlet. The revetment was extended to a jetty on the west side from 1953 to 1955, and the east jetty was constructed from 1952 to 1953. The depth of the inlet as maintained by the local governments tended to be about 3 m, with considerable sediment shoaling.

Shinnecock Inlet provides access to the Atlantic Ocean for the largest commercial fishery in New York. After a fatal boating accident of commercial fishermen, in the early 1990s the Federal Government assumed responsibility for inlet maintenance. Although the authorized depth is about 4 m including advance dredging, construction of a deposition basin to intercept sediment alongshore to the west (the predominant direction of transport except during summer), and natural deepening of the inlet channel have increased the effective depth to some 6 m. As an inlet serving major commercial fishing and recreational boating, and because the beach to the west experiences chronic erosion (Figure 3), Shinnecock Inlet and the adjacent beaches have received considerable study (e.g., Kassner and Black 1983; Williams, Morang, and Lillycrop 1998; Morang 1999; Batten and Bokuniewicz 2000; Pratt and Stauble 2000; Militello and Kraus 2001a, 2001b; Militello et al. 2001).

Despite care to maintain reliable navigability, similar to all inlets opening directly to the ocean, Shinnecock Inlet can be treacherous during storms, with waves breaking along the ebb shoal and propagating into the inlet. Current velocity in the inlet can exceed 2 m/sec, indicating that this inlet has not reached equilibrium cross section for the tidal prism it maintains (Militello and Kraus 2001a). Westward migration of the ebb jet has been identified as a mechanism for realigning the entrance channel Militello and Kraus 2001a, 2001b). During the ebb portion of the tidal cycle, the strong current can create standing waves at the mouth of the inlet, because the incident waves cannot propagate against the opposing current. Figure 4 documents such wave blocking as described by Larson and Kraus (2002). Wave blocking is a common occurrence at Shinnecock Inlet during times of low wave energy.

Occasionally, conditions in the inlet are such that incident waves can propagate into the throat and break along the western jetty. Waves approaching an opposing current, such as an ebb current, will steepen, meaning that the wave height increases and the wavelength decreases relative to the same wave propagating in quiescent water. It turns out that a wave with longer period can propagate further against an opposing current than a wave of shorter period. It is wave-steepening that often makes an inlet treacherous to navigate and why vessels will sometimes wait until ebb tide subsides before entering or exiting certain inlets, such as the mouth of the Columbia River. In contrast, waves approaching an inlet on flood tide, representing a "following current," will be reduced in height and increased in wavelength, making them flat compared to the same waves propagating on quiescent water. It is intuitively clear that surfing might be promoted by steeper waves (ebb tide), but the ebb current should not be so strong as to block the waves.

Average wave conditions along the south shore of Long Island can be characterized by a significant wave height of about 1 m, with a period between 7 and 8 sec, and predominantly from the southeast. During hurricanes and large northeast storms, wave heights can approach 3-4 m with periods ranging from 12-14 sec. Hurricane swells usually approach from the south. Locally generated wind waves are most common from the south-southeast to south-southwest, wave heights typically ranging from 1 to 1.5 m with shorter periods of 5-6 sec.

THREES

As a New York historic surf spot, Threes has been regularly surfed since at least the early 1960s, and it has been suggested that surfers may have been enjoying these clean-breaking waves as early as the initial jetty stabilization project in 1953 (Mr. Joe Alber, Westhampton, New York, a long time local surfer, personal communication). Threes is one of the few locations where a west or southwest wind blows normal to the crest of the wave, opposite the direction of wave propagation (offshore wind). Offshore-directed winds produce a smooth waveform, ideal for surfing. New York lies in the band of the Westerlies, so the global wind pattern is from west to east. The south shore of Long Island is also oriented west-southwest to east-northeast (approximately 27 deg north of east), which means west and southwest winds are side shore (blowing along the wave crest) or onshore (blowing in the direction of wave propagation) respectively. Southwest (onshore) wind generates waves that propagate toward the coast of Long Island; however, these winds create a chaotic sea state. Once the waves are generated, offshore wind, typically from the northwest, north and northeast, is necessary to organize the sea and improve surfing potential. Often, wind associated with these large, locally generated systems does not turn offshore, and the local surfing population is unable to enjoy these large waves.

The "surfability" of waves has been the subject of scientific investigation (e.g., Walker 1974; Dally 1989, 1990, 2001). Most such studies have concerned surfing environments on the open coast, away from structures. In the case of Threes, several factors control the breaking of waves inside Shinnecock Inlet, including the incident wave field properties, presence of reflecting structures, and the stage of the tidal cycle. The most limiting factor is the incident wave angle, because breaking of Threes can only occur in a narrow directional window. Shinnecock Inlet jetties are approximately oriented from north to south, with the eastern barrier offset to the south. Incident waves approaching from the southeast are blocked from entering the inlet by the orientation of the channel and offset of the barrier islands. Similarly, much of the energy associated with waves approaching from the southwest is dissipated on the extensive ebb shoal. Waves that approach the inlet from the south-southeast to the south-southwest appear to propagate into the throat and could initiate the breaking of Threes. However, if the waves travel along the axis of the channel without reflecting off the eastern jetty, they will not make their way to the western bay side shoal. These waves then propagate into the bay where they are gradually dissipated on the flood shoal or in Shinnecock Bay.

Both the tidal current velocity and water elevation alter the incident waves and exert control on the location of wave breaking. Threes was surfable 12 days between July and August 2003, and conditions were reported best from an hour or two on either side of slack low tide (Mr. Joe Alber, personal communication). During this portion of the tidal cycle, the ebb current is weak and less likely to block waves. However, a weak ebb current is expected to block or filter out the shorter period waves, resulting in waves that are longer in period, cleaner, and more surfable (Figures 1 and 5). For all of these events, the wave heights ranged between 1.5 and 2.5 m. If the incident wave height is too large, the wave will break on the ebb shoal, dissipating much of its energy before reaching the inlet. During high water, larger waves can propagate over the ebb-shoal without breaking and then through the inlet unimpeded by the ebb current. However, during high water the bay side shoal where Threes is found is also too deep to initiate wave breaking. The incident wave height needs to be small enough to pass over the outer shoals without breaking during an ebbing tide, but with long enough period to propagate against an ebb tidal current without being blocked. There is some variability in the system, and the size of the waves that will activate Threes depends on the lunar stage of the tidal cycle, as well as other external variables such as storm surge, wind direction, and wind-driven circulation.

The quality and size of the waves at Threes has also been influenced by engineering activities. The most noticeable changes occur from dredging of the main channel and deposition basin, and rehabilitation of the jetties. Dredging of the inlet allows larger waves to propagate into the throat without breaking, increasing the "source" of wave energy for Threes. Rehabilitation of the east and west jetties between 1992 and 1994, and again in 2003 has maintained or increased the reflecting potential of the structures and the amount of wave energy transmitted to the third wave (Threes). For the 2003 jetty rehabilitation, the U.S. Army Corps of Engineers, New York District, adapted construction as much as practicable to meet recommendations of the local surfing community. Thus, Threes lives on.

NUMERICAL SIMULATION OF THE THREES

To reliably or convincingly model this complicated hydrodynamic system, it was necessary to determine what conditions would cause Threes to break. Therefore, one of the authors (Buonaiuto) conducted water-borne field observations at Shinnecock Inlet, serendipitously capturing the famous Threes being enjoyed by more than a dozen surfers and one dedicated researcher on July 23 and 24, 2003. The conditions that promoted the breaking of Threes were obtained from a moored buoy located 30 nautical miles off of Fire Island Inlet (National Data Buoy Center Station 44025). The station indicated heights ranged from 1.9 to 2.3 m, periods were between 7 and 9 sec, and that the waves approached from 170 to 192 deg clockwise from the north. The wind direction at the buoy during this period was from the south-southwest and ranged from 190 to 210 deg.

Simulation Model CGWAVE

Waves propagating through this jettied inlet are influenced by wave reflection and diffraction. Numerical representation of waves inside this inlet requires a model capable of describing the variation in wave field in a confined inlet. A review of various types of wave prediction models used in coastal engineering applications is provided by Panchang, Xu, and Demirbilek (1999). It is generally agreed that models based on mild-slope equation (MSE) and/or Boussinesq equations are best suited for modeling waves at jettied inlets. These classes of wave models are based on the conservation of mass and momentum equations and are most widely applied for predicting the transformation of waves in shallow water under influence of complex coastal bathymetry and configurations of protective structures such as jetties and breakwaters. The finite element CGWAVE model (Demirbilek and Panchang 1998; Panchang and Demirbilek 2001, 2002; Panchang et al. 2000; Xu, Panachang, and Demirbilek 1996) is such a model, and it was established at Shinnecock Inlet to examine the conditions necessary for the presence of Threes.

CGWAVE can simulate regular or random waves by solving the combined MSE elliptic refraction-diffraction equation. The model is applicable to both long and short waves. The governing equations represent wave shoaling, refraction, diffraction, reflection, wave breaking, and dissipation processes in all water depths. Being elliptic, the model solves a boundary value problem that can accommodate internal non-homogeneities and boundaries. It therefore forms a well-accepted basis for performing wave simulations in coastal regions with arbitrarily shaped (engineered or natural) boundaries and arbitrary depth variations without limitations on the angle of incidence or the degree and direction of wave reflection and scattering that can be modeled. Irregular wave conditions are represented by superposition of regular (monochromatic) wave simulations (e.g., Demirbilek and Panchang 1998; Demirbilek, Xu, and Panchang 1996; Chawla et al. 1998; Zhao et al. 2001). CGWAVE calculates for a triangular finite-element formulation with grid sizes varying throughout the modeling domain based on the local wavelength. The model allows one to specify the desired reflection properties along the coastlines and other internal boundaries. The model is implemented in the U.S. Army Corps of Engineers' Surface-water Modeling System (SMS) with automated preand post-processing tools, and thus it is widely used worldwide. References providing details about this model and its capabilities, and application examples may be found at http://chl.wes.army.mil/research/wave/wavesprg/numeric/wentrances/cgwave.htp.

Model Results

Simulations were performed for wave conditions observed during storms at the site. Due to space limitations, results are presented for only one wave condition. The simulated incident condition was for regular waves from SSW (wave direction 210 deg azimuth) with height 3.3 m (10 ft) and period T=10 sec. Waves in this inlet appear to be irregular and short-crested seas with directional spreading, i.e., spectral waves. In this simulation, we assumed waves to be monochromatic (single frequency swell) for promoting visualization, and the wave-current interaction was omitted under assumption of weak current for existence of Threes. The bathymetry grid was developed from a U.S. Army Corps of Engineers SHOALS (Lidar) survey conducted on July 7, 2000 (Figure 6), and displays a large shoal on the northwest end of the west jetty. The modeling domain consisted of an offshore region bounded by a semicircle (Figure 6), the east and west jetties, and the shoreline on both sides of the inlet. At the termination of the jetties, the attached coastlines define the inlet boundaries starting from throat area through the inlet's side banks that connect inlet with the bay area. These boundaries were specified in the CGWAVE modeling to be 70% reflective in the throat and along the inlet side banks. The boundaries of back-bay area were fully absorbing to avoid potential wave reflection due to finite extent of the bay that was modeled. This would not have been necessary if the back-bay region had been modeled in its full extent. An artificial down-wave boundary was introduced at a close distance from the end of inlet to reduce the modeling domain and shorten CGWAVE computational times. By doing so, waves pass through the artificial boundary and are prevented from reflecting back into the reduced bay area or into the inlet.

Results of the predicted wave field in the computational domain are shown in Figures 7-12. The model simulations displayed the observed pattern of Threes, i.e., waves impinging on the east jetty, reflecting from it and turning northwesterly to head toward the end of the left side bank, and again reflecting from there heading toward the bay. This can be seen beautifully in the animation of wave surface profile that was generated by the SMS. The animation combines wave amplitude and wave phase (perpendicular to the direction of wave advance), and displays the wave front in time-domain as consecutive snapshots or frames. A sequence of frames over a wave period is then animated in the SMS for viewing progression of waves through Shinnecock Inlet.

Figures 7 and 8 display the two-dimensional wave field distribution in the inlet. These are snapshots taken from animation files showing wave surface elevation and wave direction together. The intensity of contours in these figures (black and white) is proportional to the wave amplitudes (heights) computed by the CGWAVE model. The vectors represent the spatially variation in the wave directions. Because of the strong reflection of waves from the jetties and inlet side banks, wave direction in such a confined inlet is strongly varying and appears somewhat confused, and thus the waves exhibit directions seen in a standing wave field in a bounded domain. Model results in these figures depict a distinct and discernable change occurring to the waves. The change takes place once waves have intercepted the east jetty. Waves striking the east jetty appear to have turned to a northwesterly direction, heading toward the end of the left inlet side bank. The model also indicates that not all waves do so and, in fact, waves unaffected by the jetties tend to move almost straight through the inlet center or graze the east jetty.

Figures 9-12 depict the situation of waves arriving at the end of the west side bank, where surfers enjoy Threes. Contours in in these figures illustrate the progression of wave fronts through the inlet. Locations where wave height contours change shape (expanding, coalescing, or disappearing) signify a local increase or decrease in wave height. Lobes (round or elongated wave height contours) developing near the end of west side bank and their merger indicate wave reinforcing (amplification) at that location. This is the instant when surfers can enjoy big waves the most. Interestingly, this increase in wave height is not sustained as waves move away from one location to another inside the inlet; wave breaking dissipates energy with distance from the end of the bank. To see the evolution of this wave field, please see animation files on our website.

CONCLUSIONS

Threes is a historic Long Island surf break produced by a fortuitous combination of interactions among engineered structures and channels, natural inlet morphology, waves, tide, and wind. When the break is active, surfers ride energetic plunging breakers along a bay-side shoal that is attached to the western barrier. Threes has been surfed since at least the 1960s and was enhanced during the jetty rehabilitation projects of the early 1990s. The U.S. Army Corps of Engineers attempts to accommodate surfing interests in preserving Threes. The complex diffraction, refraction, and reflection patterns around the ebb-shoal and inlet throat were successfully modeled with CGWAVE, numerically reproducing the wave. The model verified the incident wave directions necessary to activate the break, and illustrated the potential benefits numerical analysis can provide for engineers and surfers alike.

ACKNOWLEDGEMENTS

The authors would like to acknowledge legendary Long Island surfer Mr. Joe Alber for his insight and photographic record of Threes. We also appreciate conversations about Threes with Mr. Aram Terchunian, a Westhampton native and coastal geologist, and with Ms. Lynn Bocamazo of the New York District, U.S. Army Corps of Engineers. This work was conducted as an activity of the Coastal Inlets Research Program, U.S. Army Corps of Engineers (USACE). Permission was granted by Headquarters, USACE, to publish this information.

REFERENCES

Batten, B., and Bokuniewicz, H. 2000. Erosion criterion applied to a shoreline adjacent to a coastal inlet, *Shore & Beach* 68(2), 3-6.

Chawla, A., Ozkan-Haller, H.T., and Kirby, J.T. 1998. Spectral Model for Wave Transformation and Breaking Over Irregular Bathymetry, *J. of Waterway, Port, and Coastal Engineering* 124, 189-198.

Dally, W.R. 1989. Quantifying Beach Surfability, *Proc. 2nd Beach Preservation Technology Conf.*, Florida Shore & Beach Preservation Association, 47-58.

Dally, W.R. 1990. Stochastic Modeling of Surfing Climate, *Proc. 22nd Coastal Engineering Conf.*, ASCE, 516-529.

Dally, W.R. 2001. Improved Stochastic Models for Surfing Climate, *J. Coastal Research* SI 29, Special Issue on Natural and Artificial Reefs for Surfing and Coastal Protection, 41-50.

Demirbilek, Z., and Panchang, V. 1998. CGWAVE: A Coastal Surface Water Wave Model of the Mild Slope Equation, Technical Report ERDC/CHL TR-98-26, Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS, http://chl.wes.army.mil/research/wave/wavesprg/numeric/ wentrances/cgwave.htp.

Demirbilek, Z., Xu, B., and Panchang, V. 1996. Uncertainties in the Validation of Harbor Wave Models, *Proc. 25th International Conf. on Coastal Engineering*, ASCE, 1,256-1,267.

Kassner, J., and Black, J.A. 1983. Inlets and Barrier Beach Dynamics: A Case Study of Shinnecock Inlet, New York, *Shore & Beach* 51(2), 22-26.

Larson, M., and Kraus, N.C. 2002. NMLONG: Numerical Model for Simulating the Longshore Current: Report 2, Current and Wave Interaction, Technical Report ERDC/CHL TR-02-22, Coastal Inlets Research Program, Coastal and Hydraulics Laboratory, U.S. Army Research and Development Center, Vicksburg, MS.

Militello, A., and Kraus, N.C. 2001a. Shinnecock Inlet, New York, Site Investigation: Report 4, Evaluation of Flood and Ebb Shoal Sediment Source Alternatives for the West of Shinnecock Interim Project, New York, Technical Report CHL TR-98-32, Coastal Inlets Research Program, Coastal and Hydraulics Laboratory, U.S. Army Research and Development Center, Vicksburg, MS.

Militello, A., and Kraus, N.C. 2001b. Re-alignment of Inlet Entrance Channels by Ebb-Tidal Eddies, *Proc. Coastal Dynamics 01*, ASCE, Reston, VA, 423-432.

Militello, A., Kraus, N.C., Rahoy, S.R., Couch, S., and Weppler, P.M. 2001. Establishment of a Flood Shoal Sand Source with Preservation of Existing Habitat Function, *Proc. 14th Annual National Conf. on Beach Preservation Technology*, FSBPA, Tallahassee, FL, 327-341.

Morang, A. 1999. Shinnecock Inlet, New York, Site Investigation: Report 1, Morphology and Historical Behavior, Technical Report CHL-98-32, Coastal and Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Panchang, V., and Demirbilek, Z. 2002. Simulation of Waves in Harbors: Validation of a State-of-the-Art Model, *Proc. HYDRO' 02*, Indian Institute of Technology, Bombay, 210-214.

Panchang, V., and Demirbilek, Z. 2001. Simulation of Waves in Harbors Using Two-Dimensional Elliptic Equation Models, *Advances in Coastal and Ocean Engineering*, Vol. 7, World Scientific Publishing, 125-162.

Panchang, V.G., Xu, B, and Demirbilek, Z. 1999. Wave Prediction Models for Coastal Engineering Applications, in *Developments in Offshore Engineering*, J.B. Herbich (ed.), Gulf Publishing, Houston, 163-194.

Panchang, V.G., Xu, B., Demirbilek, Z., Schlenker, K., and Okihiro, M. 2000. Effects of Exterior Bathymetry in Elliptic Harbor Wave Models, *J. Waterway, Port, Coastal and Ocean Engineering* 126(2), 71-78.

Pratt, T.C., and Stauble, D.K. 2000. Selected Field Collection Efforts at Shinnecock Inlet, New York: Report 3, Selected Field Data Report for 1997, 1998, 1999, Velocity and Sediment Surveys, Technical Report CHL-98-32, Coastal and Hydraulics Laborataory, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Walker, J.R. 1974. Recreational Surf Parameters, Technical Report 30, Look Laboratory, University of Hawaii, 311 pp.

Williams, G.L., Morang, A., and Lillycrop, L. 1998. Shinnecock Inlet, New York, Site Investigation: Report 2, Evaluation of Sand Bypass Options, Technical Report CHL-98-32, Coastal and Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Xu, B., Panchang, V.G., and Demirbilek, Z. 1996. Exterior Reflections in Elliptic Harbor Wave Models, *J. Waterway, Port, Coastal & Ocean Engineering* 122(3), 118-126.

Zhao, L., Panchang, V., Chen, W., Demirbilek, Z., and Chhabbra, N. 2001. Simulation of Breaking Effects in a Two-Dimensional Harbor Wave Prediction Model, *Coastal Engineering* 42(4), 359-373.

Figure 1. View of Threes plunging breaker, with Shinnecock Inlet east jetty in the background (photograph source: Mr. Joe Alber).

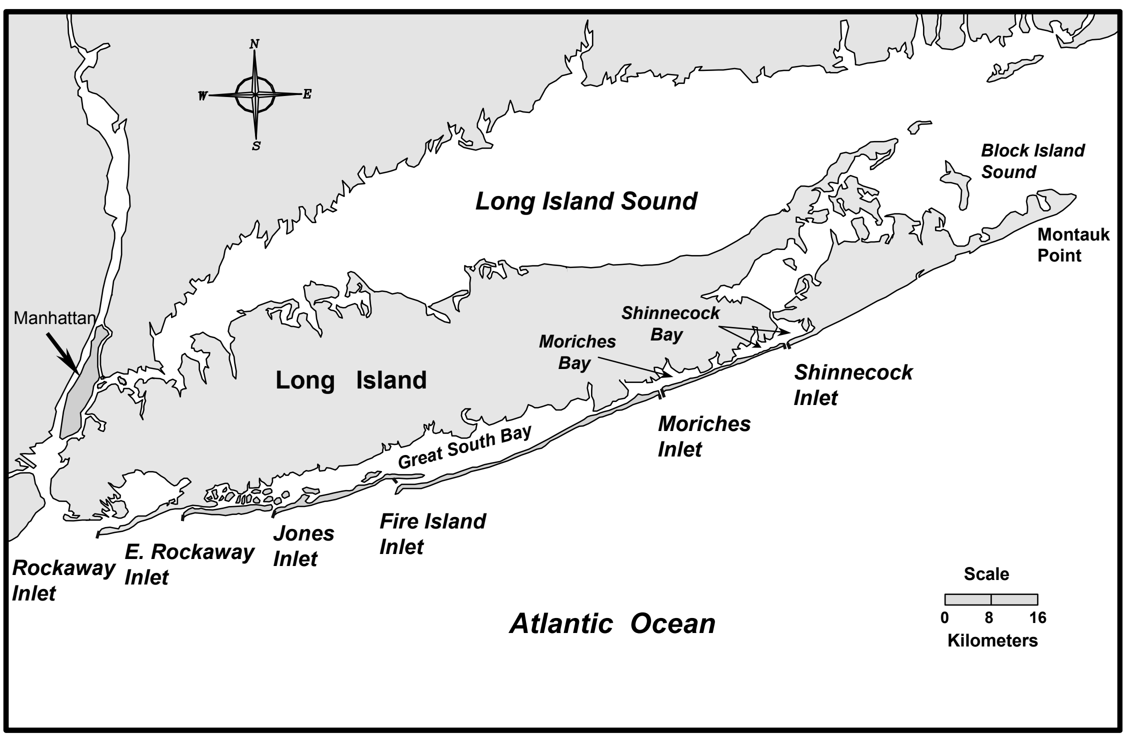

Figure 2. Location map for Shinnecock Inlet, Long Island, New York.

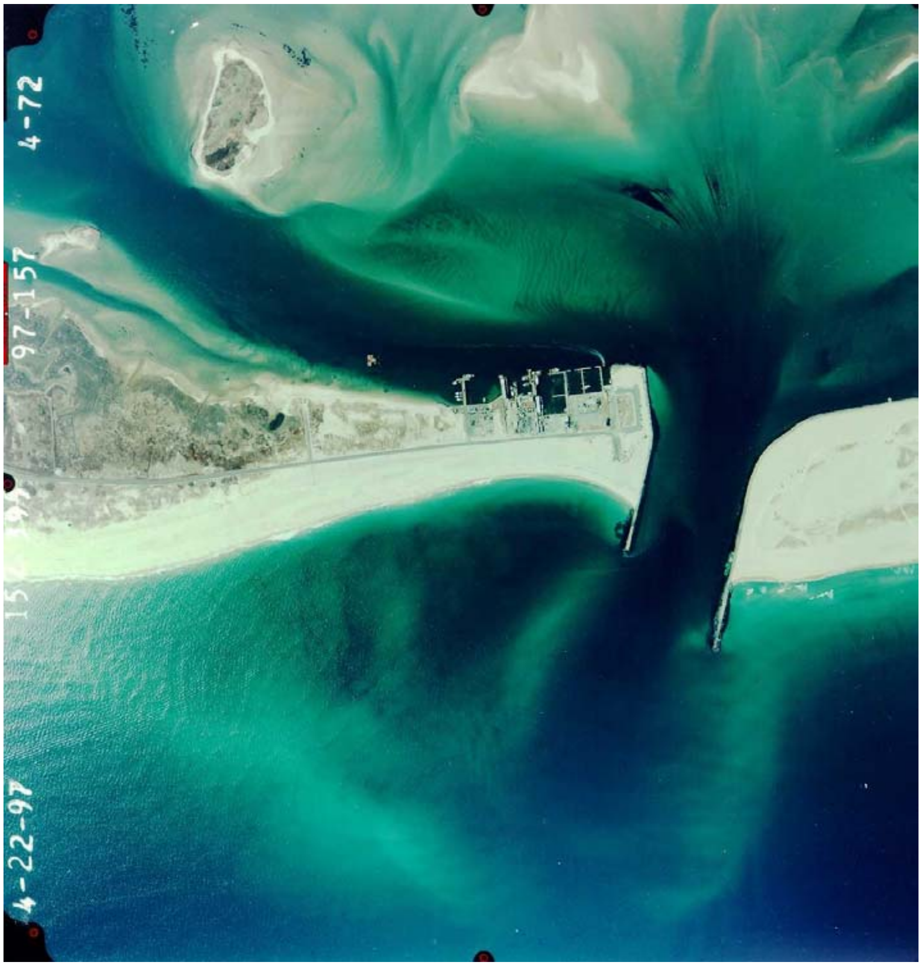

Figure 3. Aerial view of shoals at Shinnecock Inlet during a calm day, April 27, 1997. Note the shoal inside the inlet adjacent to the west (left) jetty on the bay end. Presence of this shoal is essential for creation of Threes.

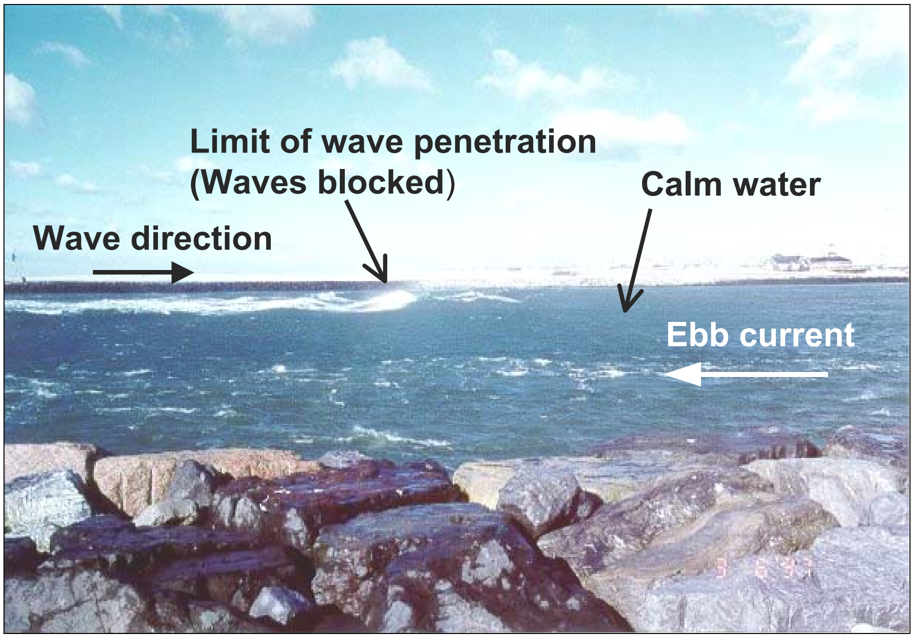

Figure 4. Wave breaking and blocking by ebb current at Shinnecock Inlet (photograph taken from east jetty looking west into the inlet).

Figure 5. Surfer finishing his ride at Threes, with fishing boat exiting the inlet and turning westward into Shinnecock Bay (photograph source: Mr. Joe Alber).

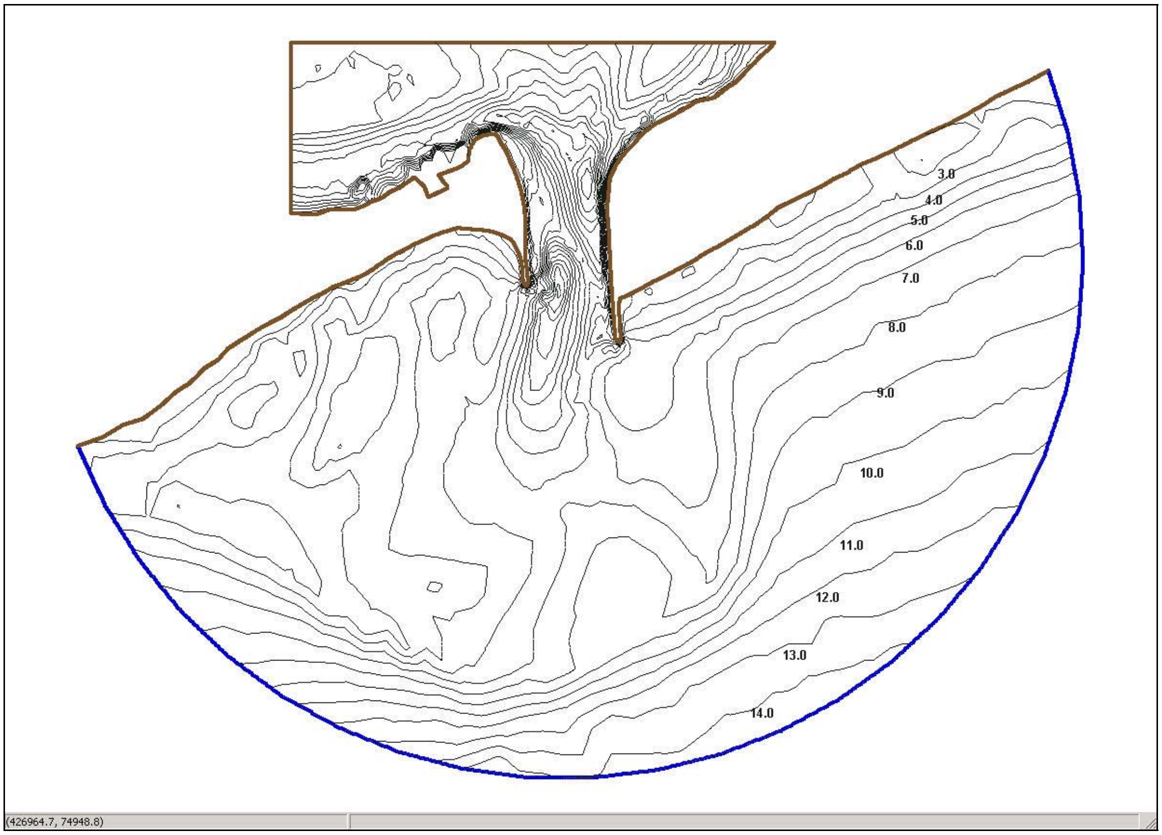

Figure 6. Bathymetry at Shinnecock Inlet, July 3, 2000 (depth contours are in meters).

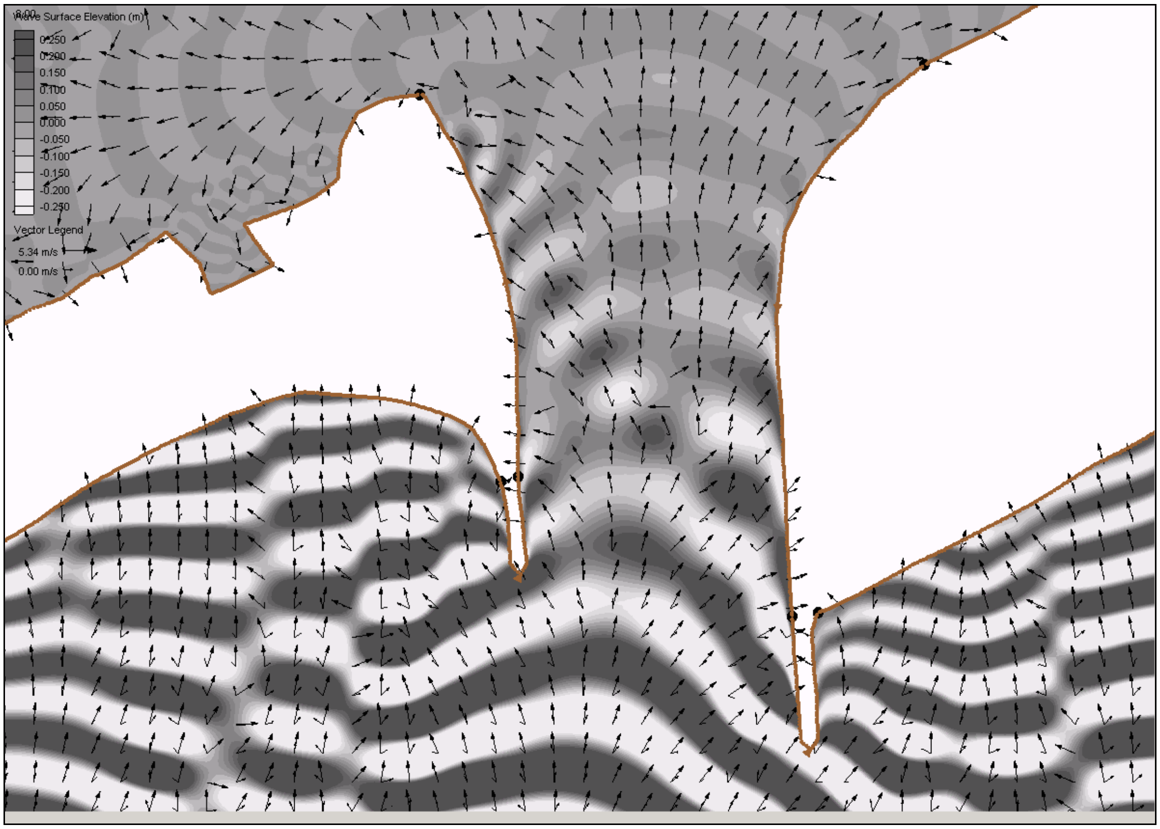

Figure 7. Propagation of waves at Shinnecock Inlet. Arrows show wave direction. Intensity of contours is proportional to amplitude of waves, i.e., high waves in dark and low waves in white.

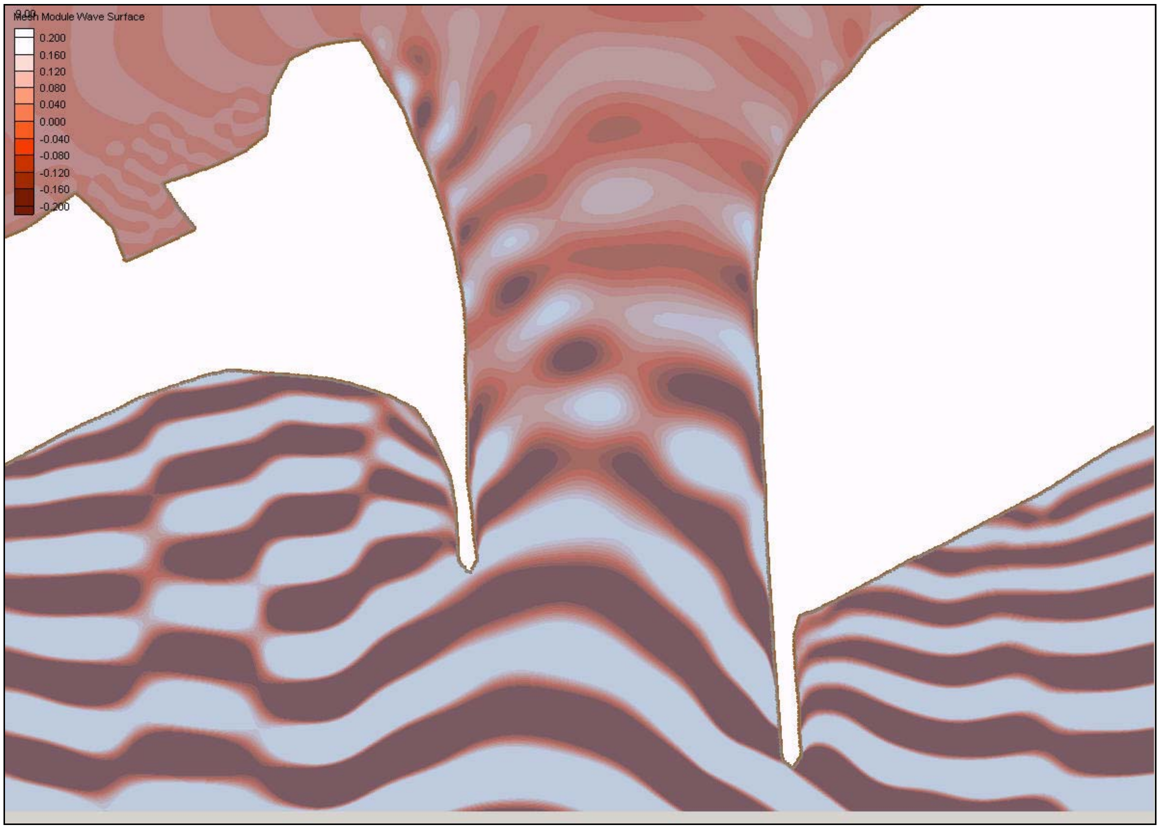

Figure 8. Propagation of waves at Shinnecock Inlet. This figures shows a snapshot of the wave fronts following their interception of the east jetty and inner bank. The round and elongated lobes heading toward the left inner bank represent the effect of waves reflecting from the right boundary and their movement toward the right inner bank and the bay.

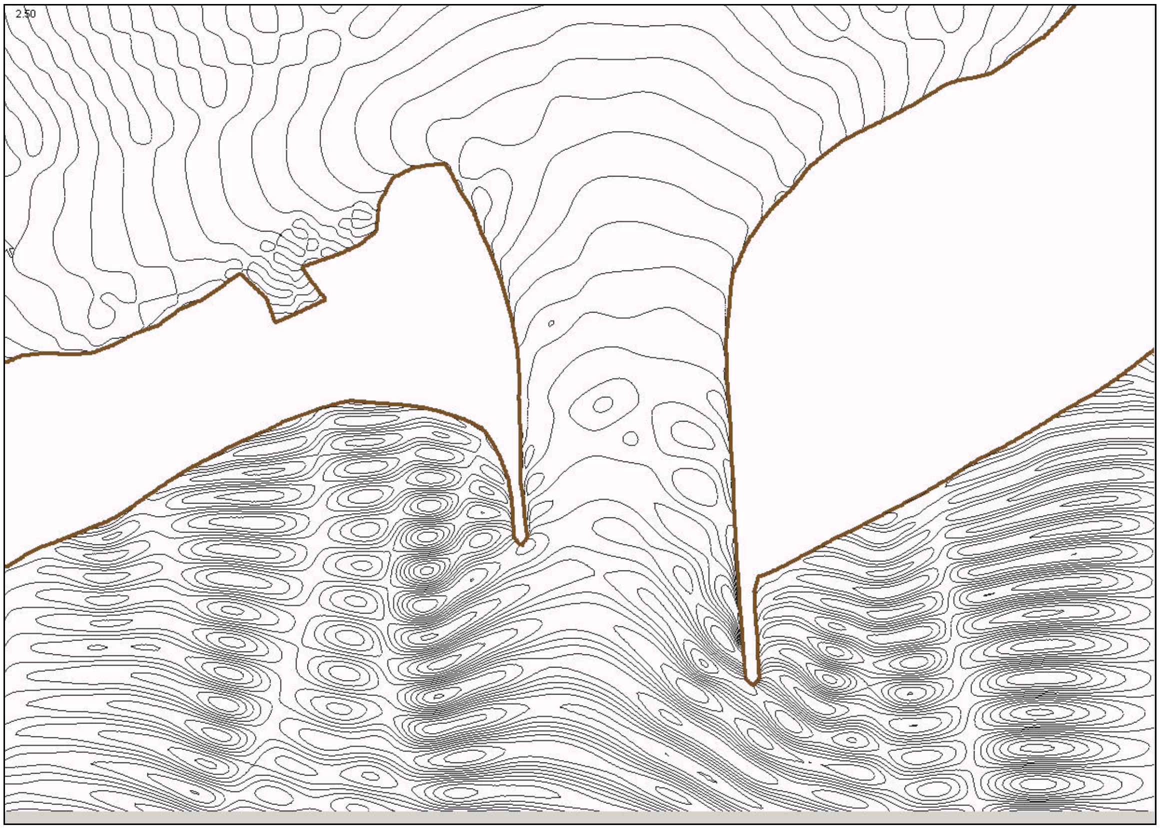

Figure 9. Propagation of waves at Shinnecock Inlet, 1.

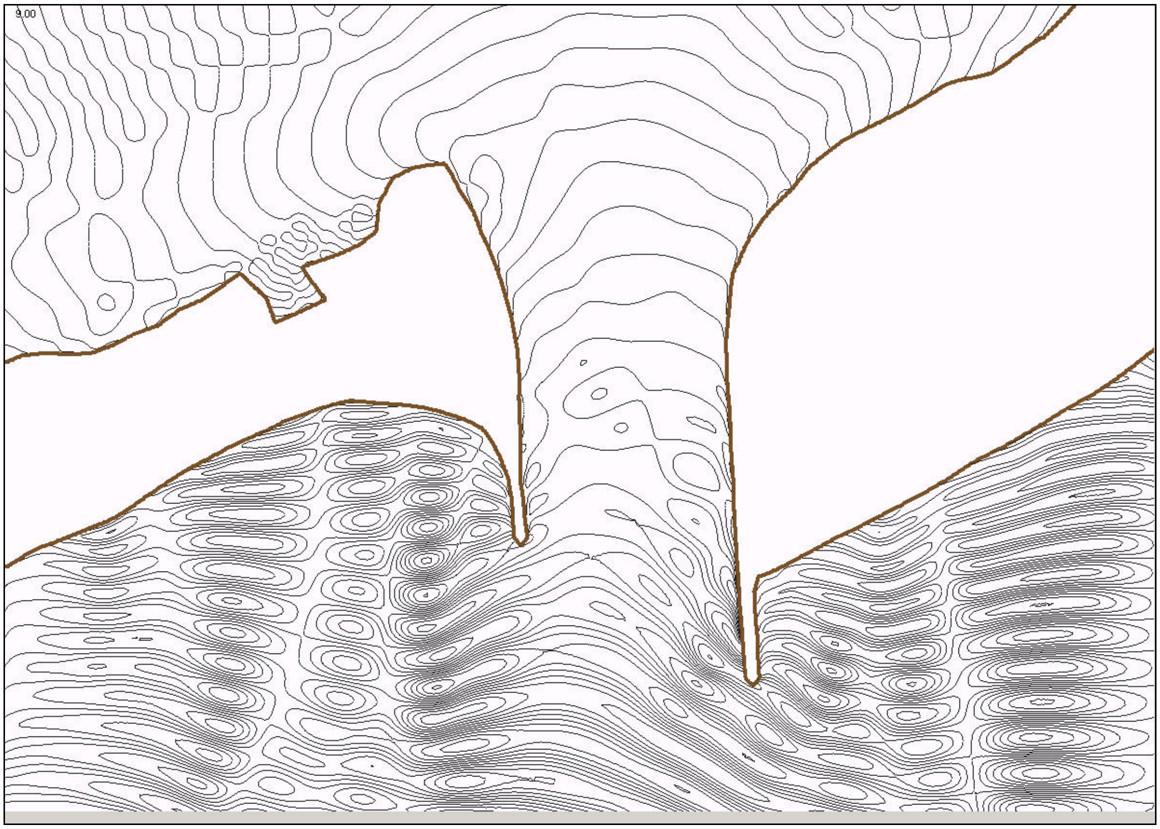

Figure 10. Propagation of waves at Shinnecock Inlet, 2.

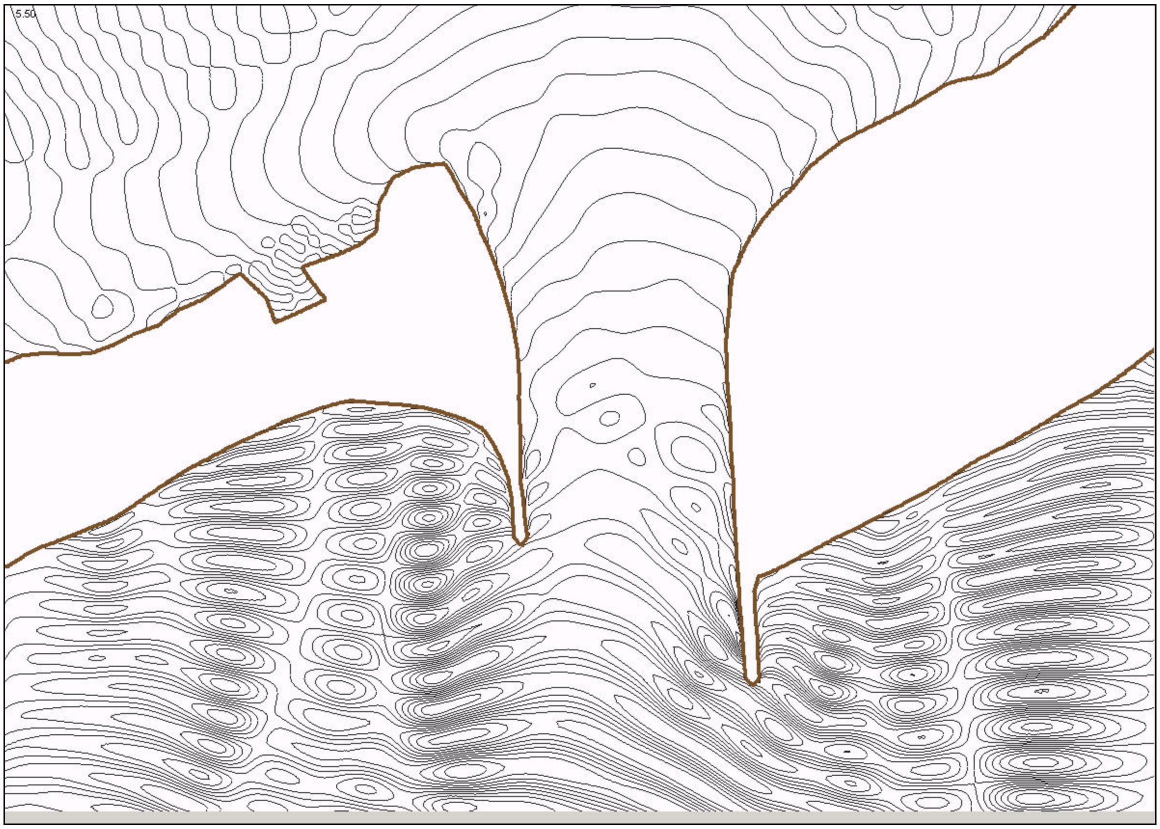

Figure 11. Propagation of waves into Shinnecock Inlet, 3.

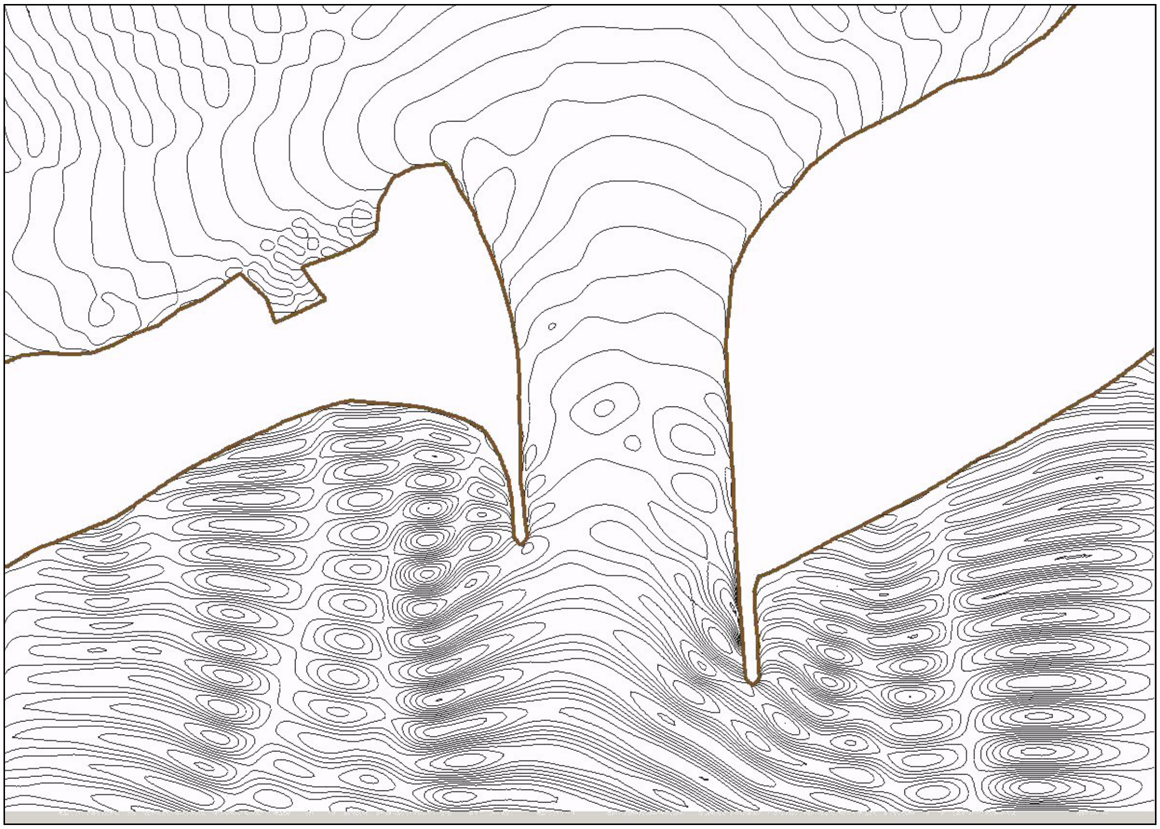

Figure 12. Propagation of waves at Shinnecock Inlet, 4.